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ENSURING THE RELOCATABILITY OF
PROGRAMS IN THE OPERATIONAL SYSTEM DOS YeS
(DOS YeS = Disk Operational System --
Unified Series)

S. K. Novosel'tsev, I. G. Orlov,
A. S. Chesalin

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ENSURING THE RELOCATABILITY OF
PROGRAMS IN THE OPERATIONAL SYSTEM DOS YeS
(DOS YeS = Disk Operational System --
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S. K. Novosel'tsev, I. G. Orlov,
A. S. Chesalin

Abstract

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In the present paper we describe modifications made by the laboratory for systems programming of the Space Sciences Institute, USSR Academy of Sciences, in the DOS YeS Operational System which ensure the relocatability of all programs used in the system.

1. INTRODUCTION

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At the present time in many computers of the YeS (Unified Series), the Disk Operational System -- DOS is used. This system ensures effective operation of small and medium modules of the YeS computers (with working storage capacity up to 256 bits) and satisfactory effectiveness of modules of YeS computers with large capacity.

An essential feature of the DOS YeS system is the fact that programs (core images or phases) ready for execution are located in a special file in a direct access device, called a core image library. Each phase in the library is completely ready for performance: every address reference within the phase is decided, the necessary programs are connected up, the address constants are adjusted relative to the proposed address for loading the memory (the initial address of the phase).

*Numbers in margins indicate pagination in original foreign text.

The procedure for assembling the phase, for adjusting the address constants and for recording the phase in the core image library is performed by the "Linkage Editor" program.

In certain cases the programmer who is preparing the program can take the Linkage Editor out of service when adjusting the address constants relative to the initial address. Ordinarily this is determined by the zero initial address of the first (or the single) phase of the program. Here the programmer provides for each core image programs of group of commands which readjust the address constants. Programs which readjust their own address constants independently are called self-relocating in the DOS YeS, since their operation does not depend on their location in the memory.

Loading the phase into the working memory for implementation /4 is accomplished by the system loader which is included in the make-up of the DOS YeS supervisor. The action of the loader in shifting core image from the library into the working memory is induced by a special request for loading. The presence of the address of the load in the request is not necessary. When an address is indicated in a request, the system loader places the phase in the working memory, beginning with the given address. If the address of the load is omitted, the phase will be located in the working memory, beginning with the initial address shown at the editing stage. In any case readjustment of the address constants by the standard system loader is not carried out.

It is obvious that the given method of editing-loading has substantial defects even under a single-program operating regime: it is difficult to create multiphase program complexes with a dynamic loading module, and when creating a new supervisor possessing large potentials (and, therefore, occupying a large volume of the working memory) it is necessary to re-edit all the programs recorded in the core image library for permanent storage.

A second editing is necessary both for user programs as well as for all non-self-relocating programs of the Operational System. If for any reason a user has no objective modules of some non-self-relocating program, i.e., if the given program is stored in the system in absolute form only, -- then it becomes impossible to use the program when increasing the core of the supervisor.

In the case of the multiprogram regime of operating the DOS YeS the disadvantages of the standard method of editing-loading increase many times over: a program edited for some particular member can only be carried out in that member. Therefore it is necessary either to attach programs rigidly to members, which leads to inefficient use of computers (since situations arise involving idle-time for individual members due to the lack of the necessary programs in their core image libraries), /5 or to edit all programs (even including the system programs) for each of the members and to locate them in different libraries. This leads to a significant increase in the size of the core image libraries and, consequently, to a large number of files on magnetic tape which are used simultaneously. Additional difficulties also arise due to the fact that it is impossible to change arbitrarily the limits of the members of the operating memory. On the other hand, the development of relocatable programs (independently adjusting their address constants) requires a rather high degree of qualification on the part of the programmer, including a knowledge of the language Assembler. For the part of such programs to be adjusted some supplementary storage capacity is necessary (besides the capacity assigned to each program). Therefore it is evident that these difficulties do not make possible any substantial increase in the efficiency of computers.

Editing linkages before each execution of a program consumes much time. For example, editing the compiler PL/1 takes up nearly 10 minutes operating time on the computer YeS-1040.

All the circumstances enumerated emphasize the need for specific modifications in the Operational System DOS YeS so as to ensure the relocatability of all programs in the System. The modifications were carried out by staff members of the laboratory for systems programming, Space Sciences Institute, USSR Academy of Sciences. The changes involved affect the linkage editor and the system loader included in the make-up of the DOS YeS supervisor.

2. A Procedure to Ensure Relocatability of Programs

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In essence the changes carried out reduce to the fact that the modified linkage editor can be included in a relocation dictionary at the assembly stage on the request of the programmer. This dictionary contains data about the length of each address constant and about its offset relative to the beginning of a core image and also the sign of the offset (which can have two values: zero or one; its use will be explained below). A request for preparation of the relocation dictionary is made with the help of a special control operator of the editor -- ACTION RL. (In the standard system DOS YeS the regime RL of the operator ACTION is absent). When the regime RL is in the table of contents for the core image library for phases prepared by a modified linkage editor, the lowest bit (not carrying information) in the address of the input point to the phase is set equal to one. A phase prepared in this manner will be called the RL-phase henceforth.

The relocation dictionary increases the dimension of the RL-phase by $4 * (M + 1)$ bytes (M is the number of address constants in the phase) in comparison with the dimension of this same phase when edited by the standard method.

For RL-phases not containing address constants, the dictionary is not constructed. The sign for the absence of the

dictionary is a "1" on the highest bit in the address of the entry point in the RL-phase.

If the regime ACTION RL is not used when a program is edited, all the phases prepared by the linkage editor will meet the standards of the DOS YeS. However, subsequently they cannot be used as relocatable (unless, of course, relocatability is ensured by the program itself).

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The modified system loader always begins its operation by determining whether the phase being processed by it is an RL-phase. (Recall that "1" in the lowest bit in the address of the entry point to the phase serves as the sign of the RL-phase). If not, then the loader operates in the standard manner for DOS YeS.

On execution of the macro-command FETCH or LOAD without giving the address of the load for the RL-phase, the system loader provides the RL-phase with an address computed according to the formula:

$$A_L = A_{CLB} + A_P + A_{LB} + A_S, \quad (1)$$

where A_L is the actual address of the load;

A_{CLB} is the address of the given phase, selected from the table of contents of the core image library;

A_P is the address of the beginning of the member;

A_{LB} is the length of the field of the label;

A_S is zero for the background member and the length of the storage field for the members of the foreground (120 bytes).

After this, as the phase is shifted into the working memory, the relocatability factor is calculated, i.e., the quantity by which all address constants of the core image are changed; the relocatability factor is computed by the formula

$$F = A_p + A_{LB} + A_S, \quad (2)$$

where F is the relocatability factor and A_p , A_{LB} , A_S are quantities defined in (1).

If the macro-command LOAD is executed for the RL-phase and the address of the load is shown, then the phase is shifted into the working memory with this address. In the given case the relocatability factor is calculated by means of the formula /8

$$F = A_{LD} - A_{LB}, \quad (3)$$

where A_{LD} is the address of the load shown in the macro-command LOAD, and the other quantities are the same as in formula (2).

Under any method of loading the readjustment of each address constant is carried out sequentially: when the value of the relocation sign is zero, the relocatability factor is added to the value of the address constant; when the value of the relocation sign is unity, the relocatability factor is calculated from the value of the address constant. The address of the point of entry into the phase is calculated by means of the formula

$$A_E = A_{ECLB} + F, \quad (4)$$

where A_E is the computed address of the point of entry into the phase;

A_{ECLB} is the address of the point of entry into the phase chosen from the table of contents of the core image library;

F is the relocatability factor.

When processing the command "Determine the address of the load" (SVC 23) for the RL-phase, the action of the system loader terminates when the value of the address of the load A (formula 1) is calculated.

It should be recalled that the length of the RL-phase with $M \neq 0$ address constants for $4 \times (M + 1)$ bytes is greater than the length of the same standard phase due to the relocation dictionary. Therefore the region into which the RL-phase is loaded must be sufficiently large in order to accommodate properly not only the text of the phase, but also the relocation dictionary.

3. The Characteristics of the Modifications Introduced Into the DOS Yes to Ensure Relocatability

In order to ensure relocatability in the DOS Yes the text of the standard linkage editor was corrected. The changes affected all phases of the editor: `oLINKEDT`, `oLINKEDTA`, `oLINKEDTC`, `oLINKEDTO`,
`oLINKEDT2`, `oLINKEDT4`, `oLINKEDT8`

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Moreover, the text of the supervisor of the system DOS Yes was corrected. The changes affected the system loader for which the macro-commands generating the supervisor FOPT and SGDFCH were modified. The capacity to operate with RL-phases is specified when generating the supervisor. For this purpose, the new parameter RL is introduced in the macro-command FOPT.

FOPT ... , RL = $\left\{ \begin{array}{c} \text{NO} \\ \text{YES} \end{array} \right\}$, ...

If the parameter RL=NO is specified, or if the parameter is omitted, then the standard DOS Yes supervisor is generated, i.e., the capacity to operate the RL-phases is not provided for.

If we generate a supervisor with the parameter RL=YES of the macro-command FOPT, then operation with RL-phases as well as with phases with the standard editing-loading procedure is ensured.

The size of the supervisor which is generated with the parameter RL=YES somewhat exceeds the size of the standard supervisor with the same potentials.

All the changes described ensure relocatability of the programs in the versions 2.0, 2.1, 2.2 of the system DOS YeS.

4. Generating and Using the Modified System DOS YeS

The modified components of the DOS YeS are supplied on a magnetic tape having the following structure:

- tape index mark;
- the input modules A.FOPT, A. SGDFCH (the length of each recording is 81 bytes);
- tape index mark;
- phases of the linkage editor (the length of each recording is 81 bytes);
- two tape index marks.

To obtain an efficient DOS YeS system which ensures per-

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mutability of programs, the user must:

1. Catalog the new input modules for generating the supervisor in the library of input modules;
2. Catalog the new linkage editor in the core image library in the resident DOS YeS volume;

3. Generate the new supervisor, after specifying the parameter RL=YES in the macro-command FOPT (after generating the supervisor it is necessary to ascertain that its actual final address does not exceed that shown in the macro-command SEND, since the size of the encoded supervisor is somewhat larger than the standard supervisor with the same parameters).

Example of a Job in Which Points 1 and 2 are Executed:

```
// JOB SYSCATAL

// DLBL IJSYSSL, ... INFORMATION ABOUT THE INDEX MARKS
// EXTENT SYSSLB, .. OF THE LIBRARY OF INPUT MODULES

// ASSGN SYSSLB, ... DESIGNATION OF THE LIBRARY OF INPUT
                        MODULES CONTAINING THE INDEX MARKS-D
                        GENERATIONS OF THE SUPERVISOR

// ASSGN SYSIPT, ... ASSIGNMENT TO A TAPE WITH MODIFIED
                        DOS/Yes COMPONENTS.

// EXEC MAINT          CATALOGING THE MODULES A.FOPT, A.
                        SGDFCH

ASSGN SYSCLB, UA       CANCEL ASSIGNMENT FOR SYSCLB.

// OPTION CATAL        CATALOGING THE LINKAGE EDITOR OF THE
    INCLUDE            DOS/Yes.

//EXEC LNKEDT/&
/&
```

To prepare relocatable programs in the modified system DOS Yes it is necessary to add the regime ACTION RL to the list of regimes and to perform the editing.

5. Limitations on the Use of the Relocatable Programs in the /11 Modified DOS YeS System

In the versions 2.0--2.1 of the DOS YeS it is possible to ensure relocatability of a program of the librarian CORGZ, the program "Editor Checkout" ATLEDT, the programs for copying and restoring, since these programs only involve operating in the background member of the DOS YeS. In order to ensure the operation of copying-restoring programs in any division of DOS YeS, it is recommended that variations of these programs be used which are supplied in versions 1.3--1.5 of DOS YeS. The given versions of the copying-restoring programs can be executed without limitation in any of the members 2.0--2.1 of the DOS YeS.

A test of the relocatability of the compilers for the algorithmic languages RPG and RPG2, and also for the programs generated by these compilers has not been undertaken.

6. The Structure of the Relocation Dictionary

The relocation dictionary consists of $M + 1$ complete words, where M is the number of address constants in a phase.

The information located in each of the M first words of the dictionary is represented in Table 1. The information located in the last word of the dictionary is described in Table 2.